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Letters to the Editor

Acoustooptics interaction in ZnO waveguides on oxidized silicon substrates deposited in DC sputtering system

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1. Introduction

The aim of this paper was to present an acoustooptic interaction in ZnO waveguides deposited on silicon substrates with DC sputtering [1]. Technique of ZnO film deposition by DC reactive sputtering has been elaborated. It has been pointed out that increase of deposition rate results in an improvement of piezoelectric and optical properties of the deposited films.

Surface acoustic wave (SAW) can be excited in a piezoelectric film with an interdigital transducer [2]. If the mentioned film is also a light-waveguide, then the acoustic wave that is propagated therein causes local displacements, which in turn result in the changes of local refractive index, due to the photoelastic effect [3]. In this way a phase diffraction grating with period equal to acoustic wavelength is generated in the wave guide.

Diffraction parameter Q is defined by the following expression [3]:

$$Q = \frac{2\pi l\lambda}{n\Lambda^2}$$

where: l – transducer aperture, λ – light wavelength in vacuum, n – refractive index of waveguide, Λ – SAW wavelength.

If diffraction parameter is greater than 1, then Bragg diffraction takes place. The maximum efficiency of diffraction occurs for light incident at Bragg angle:

$$\theta_B = \lambda/2n\Lambda.$$

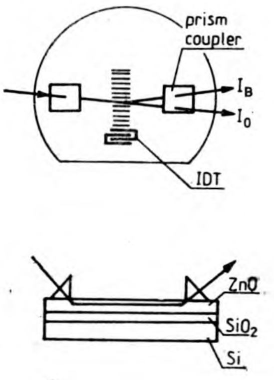
2. Experimental procedure

2.1. Light-waveguide deposition

Zinc oxide films have been deposited in DC reactive sputtering system in argon-oxygen mixture. The deposition rate was as high as 50 nm/min. In the best waveguides deposited in this system the losses were as low as 5 dB/cm, and the efficiency of acoustooptic interaction was 20%. With the decreasing deposition rate the waveguide losses increased rapidly and for 10 nm/min the films were opaque.

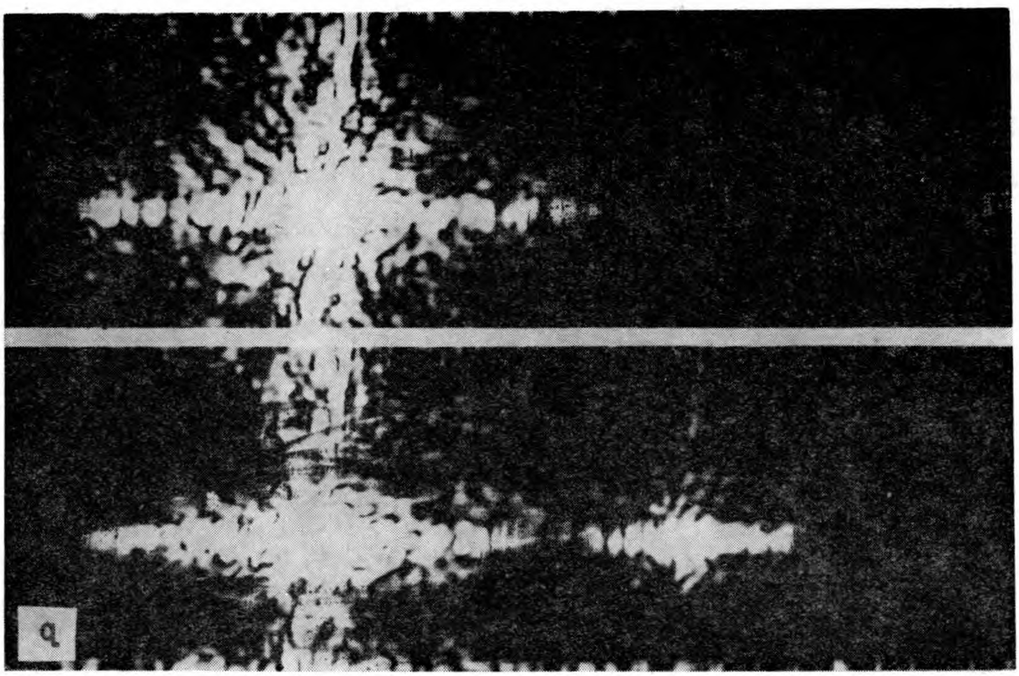
2.1. Modulator preparation

SiO_2 film has been obtained by thermal oxidation on a silicon substrate. This film has constituted an effective light-waveguide substrate to the next technological steps. The used silicon substrates, with surface smoothness typical of



a

Diagram of the planar acoustooptic modulator made of ZnO (a), and diffraction pattern before and after introducing signal into the transducer (b)



semiconductor technology, satisfied the roughness required for the deposition of light-waveguides. A 3-μm thick zinc-oxide film was deposited by DC sputtering on an oxidized silicon substrate. This film also formed a light waveguide with refractive indices of 2.0138 and 2.0.239 for TE and TM polarizations, respectively. Waveguide loss for TE_0 mode was 5 dB/cm and increased with the mode number.

The interdigital transducer's shape was defined by photolitography on the top of the light-waveguide. The transducer let SAW with wavelength of 20 μm to be generated. The calculated diffraction parameter Q was 15 for the transducer aperture of 3 mm and light wavelength of 632.8 nm. Bragg diffraction efficiency achieved the value of $20^0/_0$ for light incident angle of $\theta_B = 0.45°$. For the central frequency of the transducer amounting to the 174 MHz the SAW velocity was 3480 m/s. Figure shows a diagram of the planar acoustooptic modulator as well as diffraction pattern, before and after the signal was introduced into the transducer.

Diffraction efficiency, determined by the ratio of the deflected beam to the total light intensity, was $20^0/_0$ and $15^0/_0$ for TE and TM modes, respectively. It has been found that interaction efficiency does not depend upon the mode number and is limited by the output power of the generator employed. In the range of the applied signal amplitudes neither the damage of the film nor that of the transducer have been noticed. The mentioned above efficiency ($20^0/_0$) was achieved without electrical matching of the transducer-generator system. ZnO films were not annealed. It is expected that suitable annealing of ZnO films will increase SAW generation efficiency.

References

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